STORAGE STABILITY OF COMMERCIAL MILK

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ABSTRACT

Storage of fluid milk for extended times at low temperature appears feasible. The extended shelf life is long enough to allow a 100-fold decay of Iodine-131 under emergency conditions. This theoretical decay period may be 4 to 8 weeks depending on degree of contamination and extent of depositions on pasturage.

Commercially produced summer milk stored at 32 F, averaged 4.4 weeks or 5 times its life at 45 F. Summer milks possessed twice the shelf life of winter milks.

Shelf life was materially affected by pasteurization temperature, storage temperature, and season as determined by taste panel and bacteriological tests. Marked increases in shelf life were observed with reduced storage temperatures. Criteria for product acceptability were flavor score (35.0 or higher), total plate count, and psychrophilic plate count (less than 1 million per ml).

UHT processing at 200 to 220 F for 0.5 to 16 sec yielded as much as 20 weeks acceptable shelf life at 32 F. A combination of UHT pasteurization, 32 F storage to the end of microbial lag phase, and repasteurization followed by refrigerated holding extended storage life to as much as 23 weeks, depending on storage temperature.

The contamination of pastures and feedstuffs by radioactive fallout with consequent contamination of milk is a serious problem that has received much attention by the Atomic Energy Commission, U. S. Public Health Service, U. S. Department of Agriculture and the general public. Iodine-131, one of the important radionuclides that may occur in significant amounts in milk, is known to concentrate in the thyroid gland, thus posing a serious threat to human health. Currently, radioactive fallout does not constitute a serious threat to human health; however, in the event of an accident or emergency, sufficient information and means should be available for safeguarding our milk supply.

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To reduce exposure to Iodine-131, the Federal Radiation Council *(6)* has recommended removal of dairy cattle from contaminated pastures and the diversion of contaminated milk to processed dairy products that permit storage.

The relatively short decay period (half life = 8 days) for radioactive Iodine-131 suggests the possibility of process and storage modifications for market milk which would extend storage life sufficiently long to render it safe for use. The safe storage time would depend on the severity of the situation, i.e., the degree of contamination and the extent of depositions on pasturage. Theoretically the radioactive Iodine content would be reduced to 1/16 its original activity after 32 days storage. Russell *(14)* has reported that two months of storage would result in a reduction factor greater than 100. It can then be deduced that storage of milk for 4 to 5 weeks after a single Iodine-131 emmission probably would result in milk with a safe Iodine-131 level.

The storage stability from present pasteurizing and storage procedures strongly indicates that fluid milk might be processed and stored to maintain flavor stability for several weeks; however, practical information is lacking concerning the necessary conditions. Storage temperature is known to materially affect the keeping quality of milk. Over the years numerous reports have appeared in the literature on the keeping quality of milk and the effects of pasteurization on the bacterial flora. Considerable investigative effort has dealt with retail distribution and household storage and their effects on keeping quality *(2, 4, 7, 8, 9, 11, 13)*. Many of the early studies on keeping quality dealt with milk which was pasteurized at minimum temperatures, non-homogenized, and subsequently stored at 40 F. More recently the trend has been toward higher pasteurizing temperatures and somewhat lower storage temperature. The effects of storage below 40 F have been less conclusively evaluated. Sherman et al. *(15)* reported keeping

quality of 8 and sometimes 12 weeks for milks stored at 0 C. Boyd and coworkers *(3)* observed good flavor retention up to 42 days in milk stored at 33 F. Ashton *(2)* used strict hygienic precautions in pasteurized milk production and during storage at 36 to 38 F. Maximum keeping quality ranged from 9 to 170 days.

Undoubtedly, the advent of ultra high temperature pasteurization (UHT) has increased the capability for prolonging the keeping quality of milk. Evans et al. *(5)* reported that milk processed at 220 F for 0.6 sec hold retained bacteriological quality for 4 weeks at 40 F. Milk pasteurized at 250 to 260 F stored satisfactorily for 8 weeks at 40 F. Speck *(16)* advised that one company, using 220 F for 1 to 2 sec hold, experienced faster spoilage than when 195 F had been used. Olson *(12)* has stated bacterial types were more important than numbers in determing shelf life.

The present study was undertaken to determine whether flavor and bacterial acceptability of commercial milks or specially processed milk could be maintained long enough for Iodine-131 to decay to a safe level. It was anticipated that the study would provide the dairy industry with a standby procedure that could be used in the event of radioactive contamination of pasturage. In addition, it should provide vital information relating to the storage stability of present-day commercial fluid milk.

Experimental Procedure

Commercial milks

Commercial HTST pasteurized milk samples were secured from 6 bottling plants in six different states in the south-southeast during the summer of 1966 and again in January of 1967. HTST pasteurizing equipment included plate-vacuum and plate, steam injection, and vacuum units. Pint samples were taken directly from the paper bottle filler in each plant and immediately immersed in ice and salt until cooled to 32 F. The time required for cooling ranged from 50 to 90 min. When milk temperature, as determined by a thermistor probe inserted in a typical package reached 32 F, samples were surrounded by crushed ice in styrofoam packers for air transport to Greenville, Illinois for storage and analysis.

In-transmit time did not exceed 12 hr and temperature rise in milk samples did not exceed 0.5 F. Individual plant milk lots were divided on arrival into 4 sub-lots of 27 packages each for storage at 32, 35, 40, and 45 F. and storage temperatures were controlled to $\pm$ 1 F.

Standard plate counts (SPC) were made at each plant on the raw and pasteurized milk. Standard plate and psychrophilic counts (PPC) and flavor evaluations were made 24 hr after pick-up to establish "zero" time data for the storage samples. At weekly or more frequent intervals, duplicate samples from each plant and storage condition were examined for total and psychrophilic counts and flavor score. All bacteriological work was performed according to *Standard Methods for the Examination of Dairy Products,* 11th Edition *(1)*. Standard plates were incubated 48 hr at 32 C while psychrophilic plates were held for 7 to 10 days at 5 to 7 C before counting.

Flavor scoring followed the ADSA score card, described by Nelson and Trout *(10)*, as to numerical rating and criticism. No less than three trained flavor panelists judged each group of samples. Milk quality was considered unacceptable and analyses were discontinued when two successive stored samples showed either a bacterial count of 1 million/ml or a flavor score of less than 35.

UHT milk

UHT pasteurized milks for storage tests were processed in pilot-plant facilities at the Research and Development Division of Pet Incorporated, Greenville, Illinois. Processing equipment consisted of a modified De Laval Vacu-Therm* HTST pasteurizing system. The modification comprised installation of a spiral coil, high-velocity heater with interchangeable 0.5 and 16 sec holder tubes and an accessory high pressure pump. These units followed the heater section of the plate unit and discharged directly into the second vacuum chamber.

The system was sanitized by circulating hot water until all product contact surfaces were heated to 160 to 170 F. Thereafter 50 ppm of iodine sanitizer was added to the water and circulated 10 to 15 min. Sanitizer residue was exhausted while the system was being adjusted to the most rigorous time-temperature conditions.

Processing times and temperatures were employed in the following order: 220 F–16 sec, 200 F–16 sec, 220 F 0.5 sec, 210 F–0.5 sec.

One lot of Grade A milk was used for all conditions. Sanitizer residue was flushed with the first milk through the system and discarded.

Samples were collected in sterile 0.5–pint glass bottles from the process line partially protected from air contamination by a plastic enclosure. Process conditions were reduced to progressively less rigorous times and temperatures until samples had been collected for each of the four conditions. These lots were examined immediately for total and psychrophilic counts and flavor. They were divided into 4 sub-lots for storage at 32, 35, 40, and 45 F. Subsequent examinations of stored samples followed the plan previously outlined for the commercial samples. A total of two complete trials each comprising all four process conditions were made using summer milk and then winter milk.

Reprocessed milk

The effects of repasteurizing bulk stored milks on storage stability were determined in pilot plant facilities. Frequent plate counts indicated that the bacterial lag phase ended after 24 days at 32 F. Following the 24 day bulk storage period, milks originally processed at 220 F–16 sec, and 200 F –16 sec, were divided and each lot reprocessed at 220 F–16 sec and 175 F–16 sec. Samples of each reprocessed milk were collected in sterile 0.5–pint glass bottles for storage at 45, 40, 35 and 32 F. Analyses for total count, psychrophilic count and flavor score were made initially and at weekly intervals until samples were exhausted or exceeded criteria limits.

*Mention of brand or firm names does not constitute an endorsement by the Department of Agriculture over others of a similar nature not mentioned.

TABLE 1. RELATIONSHIP OF SEASON, PASTEURIZING CONDITIONS AND STORAGE TEMPERATURE TO STORAGE STABILITY OF COMMERCIAL MILK

Plant	Pasteurization Temp.	Pasteurization Time	Storage Life (weeks[1]) 32 F Summer	32 F Winter	35 F Summer	35 F Winter	40 F Summer	40 F Winter	45 F Summer	45 F Winter
A	169 F	16 sec	4[2]		2		2		<1	
	172 F	16 sec		4		1-3		2-3		<1
B	170 F	16 sec	4		3		2		<1	
	169.5 F	16 sec		3		2-3		2-4		<1
C	169 F	16 sec	4		3		2		<1	
	170 F	16 sec		3-5		3		1-3		1-2
D	170 F	16 sec	<1		3		3		<1-2	
	170.5 F	16 sec		1		1		1		<1
E	171 F	16 sec	7		4		2		1	
	172 F	16 sec		3		1		1		<1
F	172 F	16 sec	7		6		1-3		1	
	170 F	16 sec		1-3		1-3		1-2		<1-2
G[3]	165 F	17 sec		4		3-5		3-4		1-2
(Mean)			(4.42)	(2.83)	(3.5)	(1.92)	(2.17)	(1.83)	(0.79)	(0.79)
Std. Dev.			2.30	1.27	1.31	1.00	0.53	1.03	0.45	0.58

[1]Acceptability determined by flavor score 35.0 or higher and SPC and PPC less than 1,000,000/ml.

[2]Single number shows duplicate samples had same stability, whereas range shows difference in stability of duplicates. Value of 0.5 week assigned to <1 to permit statistical analysis.

[3]G—Plant sampled in winter only, thus not included in statistical analysis.

TABLE 2. COMPARISON OF STORAGE STABILITY CRITERIA IN EVALUATING EFFECTS OF STORAGE TEMPERATURE AND SEASON ON STABILITY OF COMMERCIAL MILK

Storage Temp.	Stability Criteria[1]	Winter Weeks Range	Winter Weeks Mean	Summer Weeks Range	Summer Weeks Mean
32 F	PPC	1-3	2.07	2-9	4.09
	SPC	1-4	2.36	2-9	4.64
	Flavor	3-5	3.36	<1-7[2]	4.42
35 F	PPC	1-3	1.36	2-5	3.17
	SPC	1-5	2.00	2-5	3.25
	Flavor	1-4	2.57	2-6	3.50
40 F	PPC	1-4	1.57	1-3	1.83
	SPC	1-4	1.71	1-3	1.83
	Flavor	1-4	2.21	2-3	2.08
45 F	PPC	<1-2	0.75	<1-1	0.75
	SPC	<1-2	0.86	<1-1	0.67
	Flavor	<1-2	1.00	<1-1	0.92

[1]Acceptability determined by flavor score 35.0 or higher and SPC and PPC less than 1,000,000/ml.

[2]Value 0.5 week was arbitrarily assigned to <1 to facilitate calculations.

TABLE 3. RELATIONSHIP OF INITIAL COUNTS, PASTEURIZING CONDITIONS AND STORAGE TEMPERATURES TO STORAGE LIFE OF UHT PASTEURIZED MILK

Milk Lot	Raw		Pasteurization			Storage Life-Weeks[1]			
	SPC/ml.	PPC/ml.	Condition	Bacteria SPC/ml.	Bacteria PPC/ml.	32 F	35 F	40 F	45 F
A	150,000	3,200	220 F-16 sec	<30 (22)	<30	13+	13+	9+	3
			200 F-16 sec	120	<30	7	4	3	1
			220 F-0.5 sec	110	<30	10	6	4	1
			210 F-0.5 sec	130	<30	9	4	3	1
E	87,000	4,700	220 F-16 sec	80	<30	13+	13+	11+	4+
			200 F-16 sec	100	<30	8	5	5	1
			220 F-0.5 sec	130	<30	12+	4	4	1
			210 F-0.5 sec	120	<30	6	6	4	1
I	14,000	7,600	220 F-16 sec	120	<30	15	14	7	3
			200 F-16 sec	130	<30	10	7	4	2
			220 F-0.5 sec	120	<30	13	7	4	2
			210 F-0.5 sec	140	<30	11	3	3	2
M	35,000	1,600	220 F-16 sec	<30 (9)	<30	20[2]	20[2]	20[2]	18[2]
			200 F-16 sec	32	<30	12	7	6	4
			220 F-0.5 sec	39	<30	12	10	6	5
			210 F-0.5 sec	31	<30	10	7	5	4

[1]Acceptability determined by flavor score 35.0 or higher and SPC and PPC less than 1,000,000/ml.

[2]Storage samples exhausted.

TABLE 4. EVALUATION OF BULK STORAGE AND RE-PROCESSING OF PASTEURIZED MILK

Initial Process	Storage Time Before Re-Past. Days @ 32 F	Bact. Pop./ml. Before Re-Past. SPC	Bact. Pop./ml. Before Re-Past. PPC	Re-Past. Conditions	Bact. Pop./ml. After Re-Past. SPC	Bact. Pop./ml. After Re-Past. PPC	Storage Stab.[1] Temp. F	Storage Stab.[1] Weeks
11-1 220 F-16 sec	24	10,000	17,000	220 F-16 sec	39	<30	45	14+
							40	19+
							35	23+
							32	23+
11-2 220 F-16 sec	24	10,000	17,000	175 F-16 sec	99	<30	45	10
							40	16+
							35	21+
							32	22+
JJ-1 200 F-16 sec	24	360,000	970,000	220 F-16 sec	77	<30	45	15+
							40	17+
							35	23+
							32	23+
JJ--2 200 F-16 sec	24	360,000	970,000	175 F-16 sec	120	<30	45	5
							40	10
							35	10
							32	19

[1]Acceptability determined by flavor score 35.0 or higher and SPC and PPC less than 1,000,000/ml.

Results and Discussion

The influence of storage temperature on the keeping quality of commercial pasteurized milk is illustrated in Table 1. At 32 F, 81% of the samples were judged acceptable for 3 weeks or longer while 57% kept for 4 or more weeks. Only 15% of the samples stored at 45 F were satisfactory for more than one week.

Summer milk exhibited significantly longer storage stability than winter milk in most instances. These seasonal differences were more pronounced at 32 and 35 F than at 40 and 45 F as evidenced both by individual and by mean storage values.

Analysis of variance revealed highly significant variations at the 99% confidence level for season and storage temperature, when using average values for stability of duplicate samples.

Variations in pasteurizing temperatures from 169 to 172 F did not affect shelf life appreciably.

A further illustration of the effect of season and storage temperature on storage stability is shown in Table 2. The storage data for all commercial milk samples are grouped as to storage temperature and season. The stability evaluation criteria, flavor, SPC, and PPC are compared in each group and generally show good agreement.

PPC was the most stringent criterion of storage life, while SPC reflected somewhat longer keeping quality. Flavor remained acceptable longest.

During the course of storage some packages became soft and were suspected of moisture wicking. To eliminate this factor as a variable, special moisture resistant, foil and polyethylene laminated packages were used to obtain additional samples from each plant during the winter phase of collection. No significant difference was noted between the two types of cartons with respect to storage stability.

The effects of storage temperature on stability of fluid milk was much more dramatic with UHT processing.

The relationships of initial bacterial populations, pasteurizing conditions, and storage temperatures to storage stability of UHT processed milk are shown in Table 3. Neither raw nor pasteurized SPC and PPC data were indicative of the ultimate storage stability. Increasing the intensity of the pasteurizing conditions materially increased storage stability. The maximum exposure of 220 –16 sec hold resulted in substantially longer storage life than obtainable from other processing conditions.

A comparison in Fig. 1 of mean storage life of UHT milk reveals the significance of process conditions and storage temperature. The beneficial effect of reducing storage temperature to prolong storage stability is shown by the curves for the lower

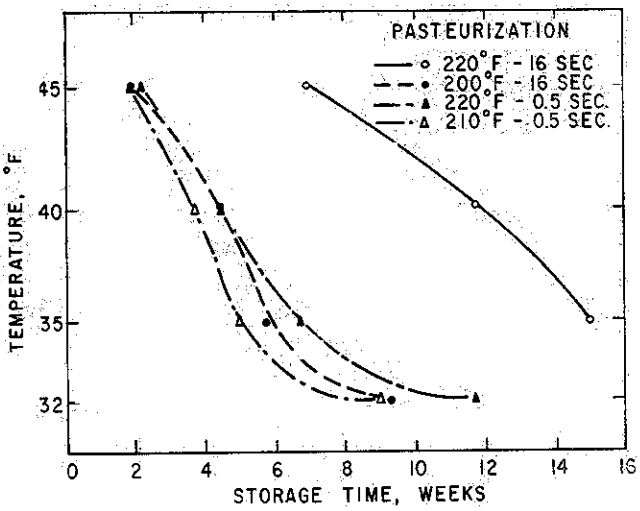

Figure 1. Storage life of UHT milk as influenced by pasteurizing temperature and time and storage temperature.

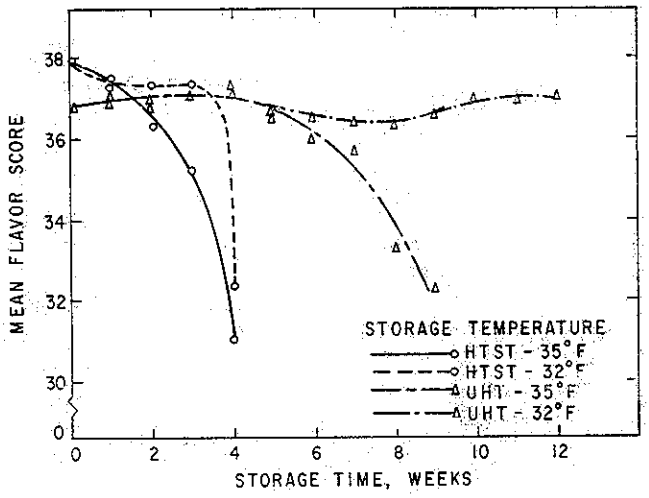

Figure 2. Comparison of HTST and UHT pasteurization as they affect flavor score and storage time.

process conditions. The curve for 220 F–16 sec is not a true representation of storage life because samples were exhausted before shelf life could be determined. Storage stability appeared to vary inversely with the storage temperature. The increase in storage stability is non-linear in that it was greater between 35 and 32 F than between 45 and 35 F.

The main flavor effects recorded for UHT samples were "cooked" during the early weeks and "stale" in the later weeks.

A comparison of mean flavor scores for commercial and UHT pasteurized milk is shown in Fig. 2. Initially, HTST pasteurized milks resulted in higher flavor score than UHT. Depending on storage temperature, the commercial milk flavor scores dropped rather rapidly, falling below 35.0 in 1 to 4 weeks. By contrast UHT flavor score was slightly lower initially, increased to a maximum of 37.5 in 4 weeks,

and remained at the 36 to 37.5 range during 12 weeks of 32 F storage and 7 weeks at 35 F.

Storage of conventional packaged milk to allow for Iodine-131 decay poses problems of package leakage, refrigeration failures, and vast refrigerated space requirements. A partial solution would be UHT pasteurization followed by bulk storage in large refrigerated tanks. With this process, milk would be held after pasteurization until initiation of the bacterial logarithmic growth phase was detected, after which it would be repasteurized, packaged, and stored under refrigeration.

Representative data for reprocessed bulk stored milks are shown in Table 4. Storage stability was longer for those milk lots receiving the most intense heat treatment.

Except for the lowest pasteurizing conditions, storage stability exceeded the number of stored samples in every instance, totaling as high as 23 weeks for several conditions.

Flavor evaluations did not indicate that repasteurization intensified cooked flavor. Staleness was the major flavor defect after 12 to 15 weeks storage.

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